Phenomenological Application of Target Theory Effects in SEE Analysis

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Section 514

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Introduction

- **Complex biological cell systems and SEE vulnerable systems have similar traits**
- **SEE defined as atypical behavior in an irradiated system**
  - Microelectronic cells may upset from ion strike
  - Biological cells may suffer critical event far earlier than predicted
- **Target theory describes events as a smooth function of total dose**
  - SEU and early cell death should not be defined well by single hit target theory that is generally used
- **Target theory should be applied in a new way**

Target Theory Model

- **Target theory describes events in low LET environment**
  - Irradiation must be mostly continuous and have complete coverage
  - Cell or bit may not recover from radiation effect

$$\frac{dN}{dt} = -\frac{N}{C} \qquad N_s = N_0 e^{-\frac{t}{C}}$$

$$N_d = N_0\left(1 - e^{-\frac{t}{C}}\right) \qquad F_{tt}(t) = \left(1 - e^{-\frac{t}{C}}\right)^D$$

  - C and D determined partially by manufacturing parameters in microelectronics

Statistical Models

- **For high LET systems, target theory will have a different coverage function, g()**
  - Discontinuous irradiation and variable coverage
  - Target recovery and TID Effects
- **Leading to:**

$$F_{tt}() = \left(1 - e^{-\frac{g()}{C}}\right)^{D}$$

$$g(\ ) = g\left(t, \dot{D}, T, \theta\right)$$

  - or even

$$g(\ ) = g\left(t, \dot{D}, T, \theta, LET\right) \qquad D = D(t, LET)$$

Statistical Models

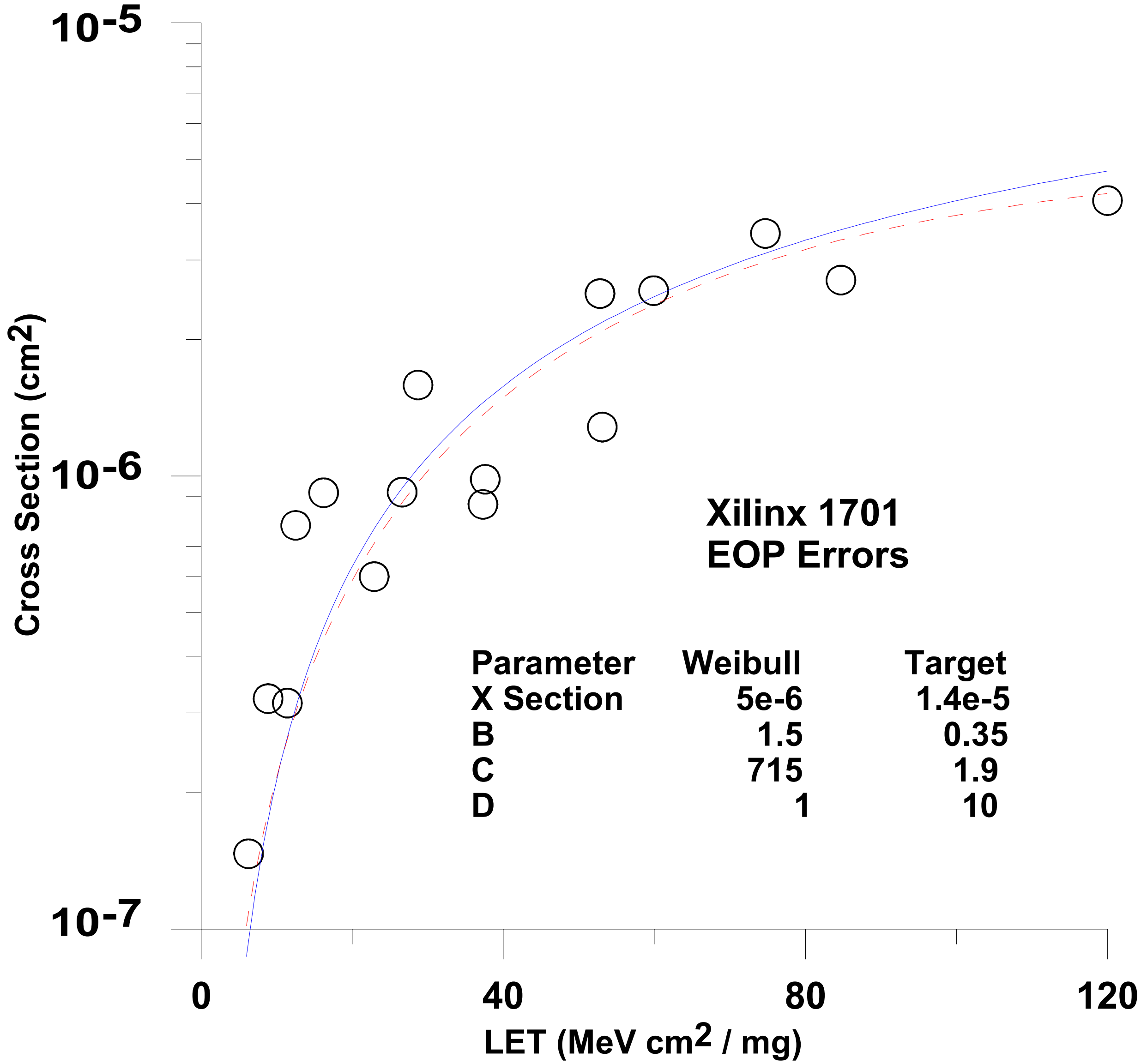
- **What could be the LET dependence?**
  - If LET and time are related, then the target theory analysis may explain SEU response.
  - Empirically, one can say that higher LET will have more effect:

$$g(\ ) = LET^{B}$$

$$F_{tt}(LET) = \left(1 - e^{-\frac{LET^{B}}{C}}\right)^{D}$$

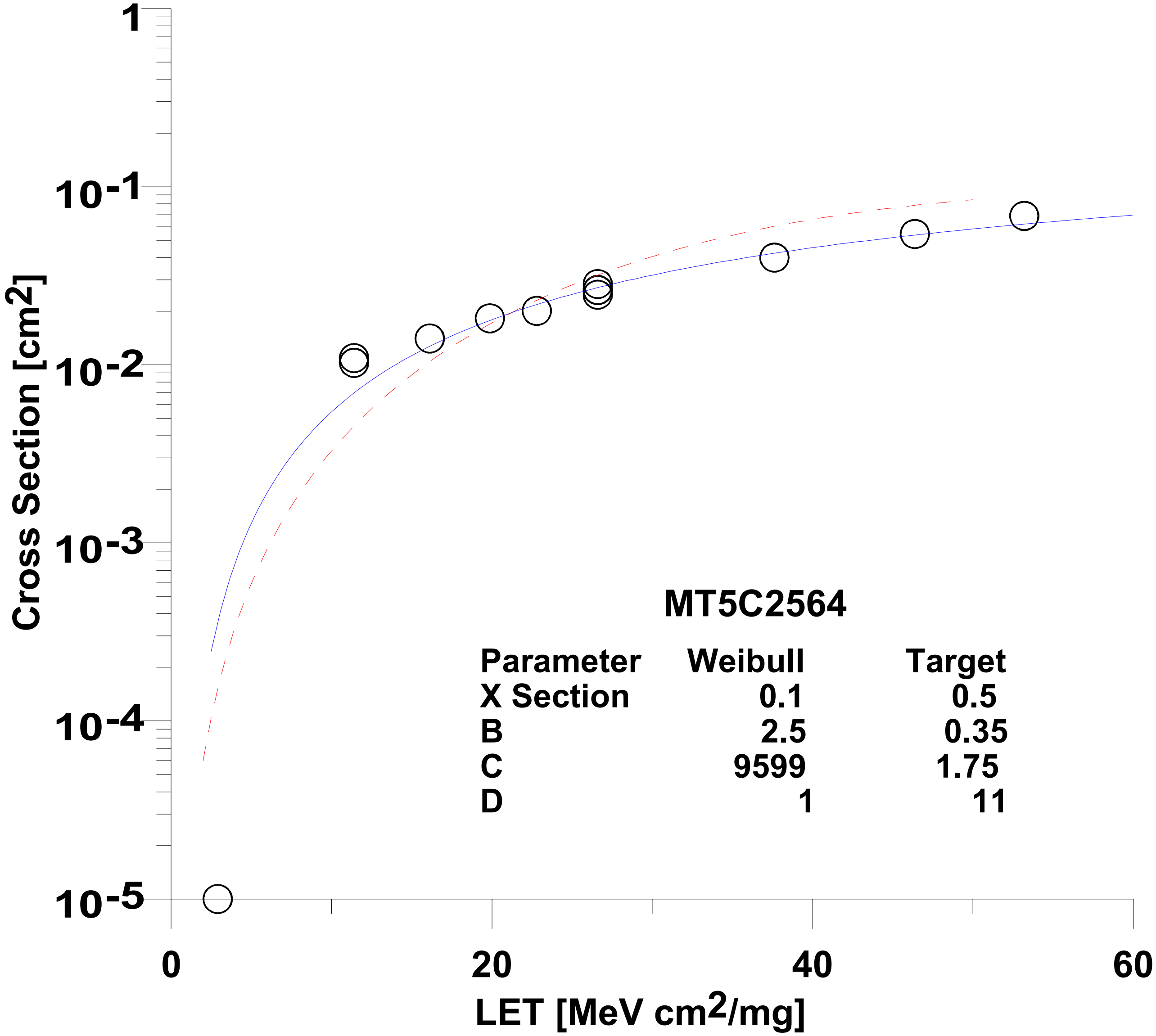
- **Much like the Weibull Or Bendel Curves**

SEU Results



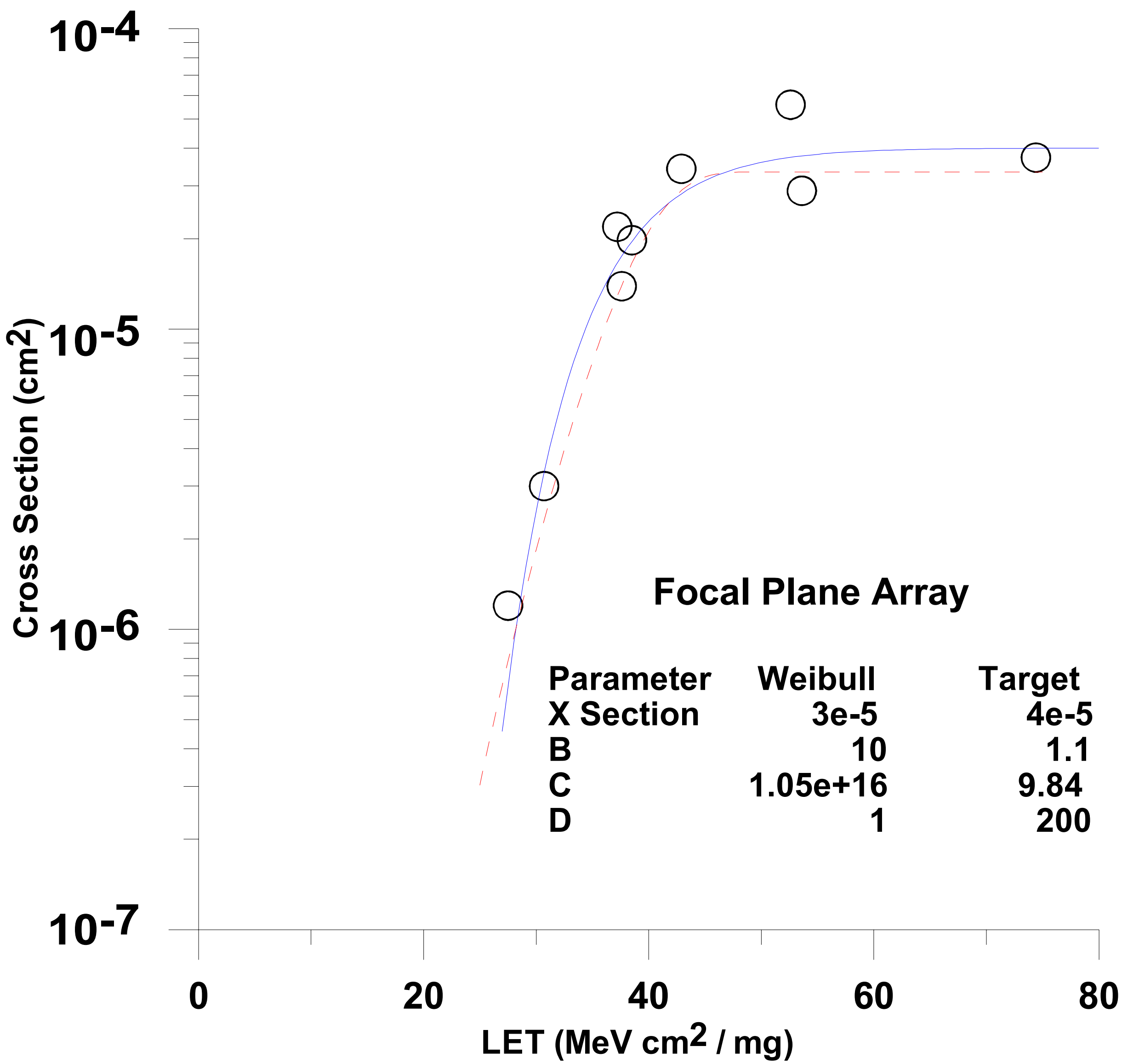
10-5
10-6
10-7
Cross Section (cm2)
0
40
80
120
LET (MeV cm2 / mg)
Xilinx 1701
EOP Errors
Parameter Weibull Target
X Section 5e-6 1.4e-5
B 1.5 0.35
C 715 1.9
D 1 10

SEU Results



1
10-1
10-2
10-3
10-4
10-5
Cross Section [cm2]
0
20
40
60
LET [MeV cm2/mg]
MT5C2564
Parameter Weibull Target
X Section 0.1 0.5
B 2.5 0.35
C 9599 1.75
D 1 11

SEU Results



Focal Plane Array
Parameter Weibull Target
X Section 3e-5 4e-5
B 10 1.1
C 1.05e+16 9.84
D 1 200
Cross Section (cm2)
LET (MeV cm2 / mg)
10-4
10-5
10-6
10-7
0
20
40
60
80

Radiation Variance

- **What do the parameters mean?**
  - B is the Weibull shaping parameter
    - Production variable
  - C is a hybrid parameter
    - Related to the LET threshold of the device
    - B and C together determine the behavior at low LET
  - D is the target theory parameter
    - Determines the behavior at high LET
    - C and D together determine behavior at high LET
  - Correlates to sensitive volume
    - Complex function of B, C, D

Applications: SEU Prediction

- **Exact distribution must be known**
  - High precision required for low LET SEU prediction
- **Knowing parameters of the distribution allows for prediction of threshold events**
  - Analyses like Extreme Value theory are very dependent on distribution precision
- **Re-evaluate lifetimes of systems in inhomogeneous radiation environments**
  - Target theory can describe accrual of interface states concurrently with SEE effects

Future Directions: Microvolume Analysis

- **Threshold LET may give valuable insight to SEU dynamics**
  - Extrapolation to radiobiological application
- **Statistics of Microeffects**
  - Threshold LET measurements should allow sensitive volume measurements
  - Using D to get number of targets, C to get target threshold and B to get target distribution should reveal sensitive volume structure

Summary and Conclusions

- **Target theory analysis highly dependent on probabilistic charge collection by SEU sensitive regions**
  - Good Points
    - Three degrees of freedom in fitting SEU cross section curves
    - Can be extrapolated to hybrid TIP/SEE studies
  - Bad Points
    - Parameters convolute in any kind of fitting procedure
    - Approximations made in derivation dilute parameters
    - Does not predict maximum cross section